BACKGROUND: As an essential hospital facility, the central oxygen supply system should be
designed with features allowing backup and/or redundancy in the event of system failure. As part of an 
organized institutional review of The Cleveland Clinic Foundation hospital inpatient central 
oxygen supply system, we undertook a survey of all hospitals in two Ohio cities to determine the 
characteristics of hospital central supply systems. METHODS: The questionnaire was developed 
and completed by structured telephone interview during calls placed to managers of facilities 
engineering departments in 35 hospitals in the greater Cleveland and Columbus, Ohio, metropolitan areas. To encourage candid responses to the telephone interview, respondents were assured that institutional names would not be presented in published reports. The questionnaire addressed the type of primary and reserve oxygen sources in the hospital, whether a backup system exists, and if so, in what configuration. The questionnaire also addressed whether any unplanned interruption or other problem (such as contamination of the piped-in oxygen supply) had ever occurred in the facility. RESULTS: Of the 35 eligible hospitals, responses were available from 32 (91.4%). The mean number of beds in the hospitals responding was 397 ± 251 (standard deviation), and the original construction dates of the responding hospitals ranged from 1887 to 1982. All 32 responding institutions reported a reserve system, described as a liquid reservoir in 72% (23/32), manifolded cylinders in 16% (5/32), and both in 13% (4/32). Twenty-six (81%) of those responding reported having the reserve supply liquid or manifolded gas cylinders at the same location as the primary liquid vessel. The supply lines of these contiguous primary and reserve containers were reported to join proximal to entering the hospital structure, so at each of these 26 hospitals the primary and reserve systems depend on a single length of pipe. Only 4 (13%) of the hospitals have manifolded cylinders in addition to the primary and reserve liquid supplies. These manifolds are in different locations from the primary and reserve, have physically separate feed lines, and represent the only true examples of redundant piped-in oxygen supplies recorded during the survey. Of the 32 hospitals surveyed, 5 (16%) reported having experienced mishaps with the bulk liquid supply. CONCLUSIONS: (1) Not surprisingly, most of the hospitals in these two urban areas use bulk liquid oxygen systems (with primary and reserve liquid reservoirs) as the main central supply source, with some providing manifolded cylinders as backup. (2) Mishaps regarding the main supply line from the bulk oxygen reservoir were reported by 16% (5/32) of responding institutions. (3) In this context, the fact that most main and reserve tanks were contiguous and fed through a single line to the hospital facility suggests ongoing risk for interruption of an oxygen supply by line mishaps (e.g., street repair). (4) Contingency planning to lessen the risk of an interrupted supply should involve back-up systems with physically separated feed lines, as well as tanks of manifolded cylinders along the course of the main hospital oxygen circuit line. [Respir Care 2000;45(3):300–305] Key words: oxygen, central oxygen supply, oxygen reserve system.
Background

Providing supplemental oxygen to hospital inpatients requires a carefully engineered system, whether by liquid oxygen fed from a common source tank or by multiple pressurized cylinders localized throughout the hospital. Although supplemental oxygen provides a critical life-support need for many hospitalized inpatients (eg, those in the operating room or intensive care unit), relatively little attention has been given to issues of backup systems or disaster strategies in the event of failure of the main supply system. Indeed, the possibility of such a system failure, given the critical need for a reliable and redundant hospital inpatient oxygen supply, likens supplying inpatient oxygen to the “Y2K” problem of preparing computers for the new millennium. In particular, the similarities are:

1. Like “Y2K” issues, problems with the hospital oxygen supply may be invisible until they occur.
2. As with computer problems, by the time the oxygen supply is interrupted, the consequences may be severe.
3. Because any reaction at the time the problem occurs could be inadequate to avert serious consequences, an expectant approach is recommended.

Methods

A questionnaire was administered by structured telephone interviews during calls placed to the chiefs of facilities engineering at all 34 other hospitals in the greater Cleveland and Columbus, Ohio, metropolitan areas. Responses for The Cleveland Clinic Foundation were provided by the study investigators, who were members of the Department of Facilities Engineering and Section of Respiratory Therapy. The questionnaire addressed what type of central hospital oxygen supply system exists, whether mishaps involving the central oxygen supply system had occurred, to the respondent’s knowledge, whether a backup system exists, and, if so, details of its configuration. To maximize compliance with questionnaire response, the anonymity of responding institutions and responding individuals in published reports was assured.

The questionnaires were administered by two of the study investigators (JB and MS), both of whom were knowledgeable regarding hospital oxygen supplies in their respective capacities as supervisory registered respiratory therapist and senior engineer in The Cleveland Clinic Foundation facilities engineering group.

If the director of facilities engineering could not be reached, a follow-up call for questionnaire completion was placed to the director of respiratory care.

Results

As listed in Table 1, 35 hospitals (24 in Cleveland, 11 in Columbus) were surveyed, and responses were available from up to 32 (91.4%) of the institutions. Respondents were directors of facilities engineering in 81% (26/32), directors of respiratory therapy in 13% (4/32), and respiratory therapy instrumentation coordinators in 6% (2/32). The size of responding hospitals ranged from 26 to 1,000 beds (mean 397 ± 251 [standard deviation], median 356). All respondents reported that central oxygen supply systems consisted of bulk medical gas with a primary liquid cylinder. The hospital construction dates ranged from 1887 to 1982 (median 1955), though central oxygen supplies were considerably more recent (1959 to 1989, median 1973).

Although the amount of oxygen used per day was infrequently known by respondents (3/32), hospitals for which the daily oxygen consumption was known reported using 9,000 cubic feet, 4,300 gallons, and 133,333 cubic feet per day. All 32 responding institutions reported a reserve system, described as a liquid reservoir in 79% (23/32), manifolded cylinders in 16% (5/32), and both in 13% (4/32).

Twenty-six (81%) of those responding reported having the reserve supply liquid or manifolded gas cylinders at the same location as the primary liquid vessel. The supply lines of these contiguous primary and reserve containers join proximal to entering the hospital structure, so that the primary and reserve of these 26 hospitals are dependent on...
only a single length of pipe. Only 4 (13%) of the hospitals reported having manifolled cylinders in addition to the primary and reserve liquid supplies. These manifolds are in different locations than the primary and reserve, have physically separate feed lines, and represent the only true examples of redundant piped-in oxygen supplies recorded during the survey.

In the context that few respondents knew the average daily institutional oxygen consumption, it was not surprising that the mean duration of the backup system supply was infrequently known to respondents (6/32, 19%). In 6 instances, the mean backup duration was estimated to be 16 hours. Availability of an emergency outside low-pressure oxygen connection (eg, for tanker truck hookup) was reported in 63% (20/32), but 3% (1/32) of respondents were uncertain about the existence of such a hookup, and 34% (11/32) reported having no such connector. Notably, 16% (5/32) of respondents reported having experienced at least one mishap involving the main oxygen supply system, 75% reported no problems, and 9% were uncertain. Damage to the supply line from the primary reservoir or to the main line delivering gas to the hospital was responsible for the supply mishap in all 5 instances. In 4 of the 5 instances, the main underground supply line was inadvertently cut during nearby construction and/or street repair. In one instance, debris falling from the roof of an
adjacent structure during a windstorm damaged the supply line from the primary liquid reservoir, but the reserve bulk reservoir was activated as designed, averting an interruption of oxygen supply. In the 4 instances in which the main supply line was interrupted, the reported duration of interruption was 3–4 hours in three hospitals, but was unknown in the fourth. In no instance of central oxygen supply interruption was an adverse patient outcome reported.

Responses to the 4 main supply-line interruptions included delivery of a tanker truck (n = 1), activation of a manifolded cylinder bank (n = 2), and back-feeding oxygen from cylinders (n = 1).

Problems other than interruption of the oxygen supply were described in one instance in this series. The event regarded inadvertent and unsuspected crossing of oxygen and nitrous oxide lines to anesthesia machines in the operating room at a time before oxygen analyzers were routinely in use. The resulting inadvertent delivery of nitrous oxide instead of oxygen reportedly contributed to the deaths of two patients. Among the remaining 31 respondents, problems other than interruption of the main supply were not reported (88%, 28/32) or were unknown to the respondents (9%, 4/32).

Discussion

The main finding from this survey regarding hospital central oxygen supply systems is that mishaps regarding the central oxygen supply were surprisingly common (16% [5/32] of responding institutions). Fortunately, despite interruptions of the main oxygen supply for up to 4 hours in the current series, contingency plans were exercised, with no adverse clinical effects from main supply line interruption. One reported gas mishap that was unrelated to the central oxygen supply consisted of crossing oxygen and nitrous oxide in the operating room and was associated with serious consequences.

Although similar mishaps have been described in past case reports, the current study extends prior understanding by surveying hospitals in two large cities to estimate the rate of such mishaps. In one earlier (1976) survey regarding hospital central gas mishaps, Feeley and Hedley-Whyte administered a mail survey to 200 hospital directors of anesthesiology to ascertain the frequency of malfunction of hospital oxygen and nitrous oxide systems. Based on the 88% of responses, 31% (n = 59) of respondents reported 76 incidents, which caused 3 deaths. One of the fatal mishaps regarded gas lines that were crossed during
new hospital construction, and 2 fatalities related to contamination of an existing oxygen supply (with nitrogen gas). Overall, at least 6 (8%) of the 76 incidents involved malfunction of existing central gas supply systems. Insufficient oxygen pressure accounted for 51% (n = 37) of the 76 incidents, while excessive pressures were reported in 9%. Failure of low-pressure alarms, predisposing to depletion of oxygen supplies, was reported in 4 instances (5%), and low oxygen flow occurred twice (3%). Excluding the instances of crossed pipes, contamination of the oxygen supply in an established central supply system was reported in 2 instances (3%), once when the supply vessel was filled with nitrogen (causing 2 deaths) and once when water contaminated the line. Finally, one instance of a leak in the oxygen pipeline was reported.

Of the 37 instances when oxygen pressure was reported low, causes were specified in 30, and included: pipeline damage during nearby construction activity (n = 8), pipeline blockage (n = 6), oxygen depletion because of insufficient capacity (n = 6), freezing of a regulator during delivery (n = 4), unannounced system shutdowns by engineering (n = 3), lightning damage to the main reservoir vessel, (n = 1), regulator malfunction (n = 1), and installation of wrong wall connectors (n = 1). Although the status of backup oxygen supply systems was not the subject of the 1976 survey, it appears that at least 26 of these 37 instances of low or absent oxygen pressure might have been averted by availability of adequate backup oxygen supplies.

Since publication of the results of the 1976 survey, MEDLINE and Lexis-Nexis searches of the indexed medical and popular literature found 8 additional reports of mishaps with central oxygen supply systems (Table 2). Five of these instances involved contamination of the central oxygen supply, either by introduction of toxic substances (eg, carbon tetrachloride, argon) during delivery of liquid oxygen to the main storage vessels (n = 3), or by contamination with air through existing pipes (n = 2). Three instances regarded oxygen leaks, either due to human error during delivery of liquid oxygen (n = 2) or due to earthquake damage to pipes (n = 1). Two instances regarded inadvertent crossing of supply lines containing oxygen and nitrous oxide.

Conclusions

Overall, available results from the current survey and prior reports suggest that inadvertent interruption of the main oxygen supply line from the bulk reservoir to the hospital occurs relatively frequently (ie, in 12.5% [4/32] of the responding institutions in this series) and is the most common cause of oxygen main supply interruption. The need for greater attention to labeling and protecting the main supply line is clearly suggested. The results of our survey also suggest several specific measures to lessen the risk of mishaps involving the hospital central oxygen supply:

1. Hospitals should conduct a systematic audit of their central gas supply systems regarding the rate of daily oxygen consumption, the presence and adequacy of a backup system, and the existence of a specific contingency plan in the event of an interruption.
2. Central oxygen supply systems should incorporate several important design features:
   a. Prominent labeling and shielding of the oxygen feed lines that connect the main supply vessel to the hospital, so as to avert accidental interruption (eg, during street repair),
   b. Availability of a backup supply vessel, ideally located remote from the main vessel and with separate feed lines to the hospital, and
   c. Ample valves along the oxygen supply line within the hospital, so that leaks can be isolated without interrupting the central supply to the entire institution.

Although the present research is only the second survey that, to our knowledge, has systematically addressed the rate and spectrum of mishaps, several important shortcomings of this study are noteworthy. First, the response rate was incomplete, with some responses available in as few as 22% (7/32) of hospitals surveyed. In instances in which responses were available from the minority of institutions addressed, sampling bias remains a concern. Another potential bias affecting our results is that, despite the promise of nondisclosure of institutional identity by the investigators, reluctance by respondents to candidly volunteer adverse hospital experiences might be expected, causing the rates and even severity of adverse events to be underestimated in this series. Finally, our survey did not systematically address gas mishaps unrelated to the central hospital gas supply (eg, interruptions of oxygen lines in anesthesia machines serving individual patients). However, as has been discussed by Anderson and Brock-Utne, such interruptions also may occur, and it is critically important for the managing clinician to have a systematic approach for identifying the specific cause of oxygen interruption.

Notwithstanding these potential study biases, we believe that the reported frequency of oxygen supply mishaps should prompt clinicians, administrators, and hospital facilities personnel to review the status and contingency plans regarding their hospitals’ central oxygen supplies, so as to avert the substantial risks of unanticipated failure. In this way, the “O2K problem” can be avoided.
REFERENCES

3. The Toronto Star; Apr 10, 1974.